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Analyzing the Effect of Footprint Size and Spacing on ICESat-II Accuracy

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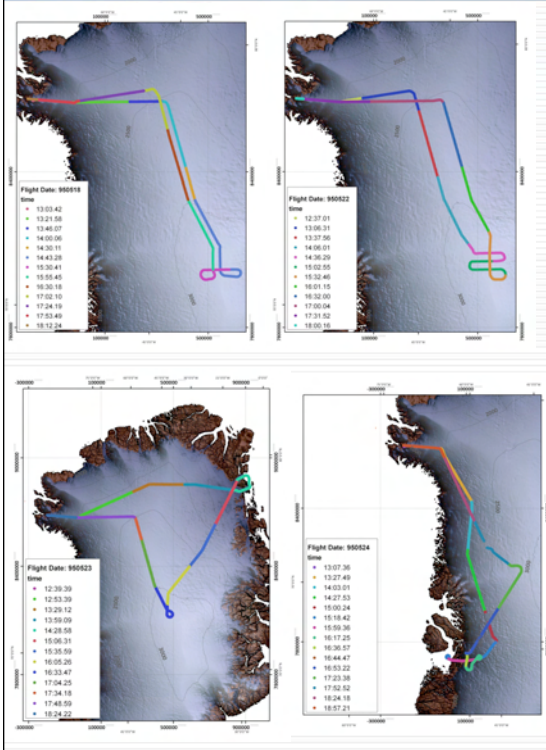


1995/96, ATM Data Acquisition in Profiler Mode

Frequency f = 2000 Hz

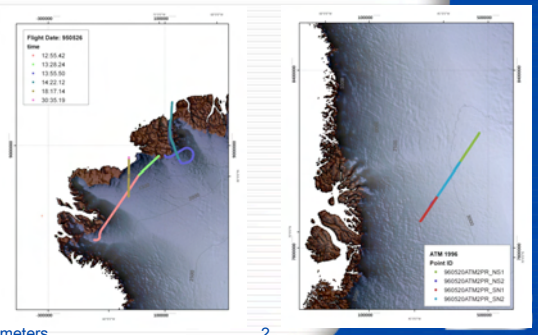
Velocity v ~ 100 m/s

➔ spacing between neighboring points = v/f ~ 0.05 m

Flying height H ~ 400 m above ground

Divergence angle = 25 mrad

➔ footprint size = H ~ 1 m



Previous Work

van der Veen, C. J., W. B. Krabill, B. Csatho, and J. F. Bolzan, 1998. Surface roughness on the Greenland ice sheet from airborne laser altimetry. Geophysical Research Letters, 25(20), 3887-3890.

van der Veen, C.J., Y. Ahn, B. Csatho, E. Mosley-Thompson and W.B. Krabill, in review. Surface roughness over the northern half of the Greenland ice sheet from airborne laser altimetry. Journal of Geophysical Research, Earth Surface

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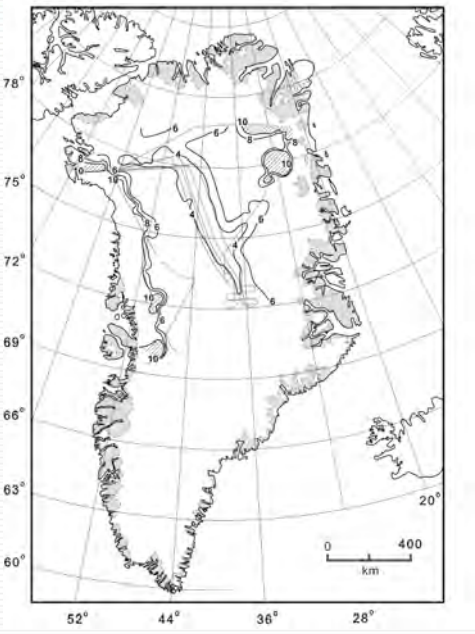
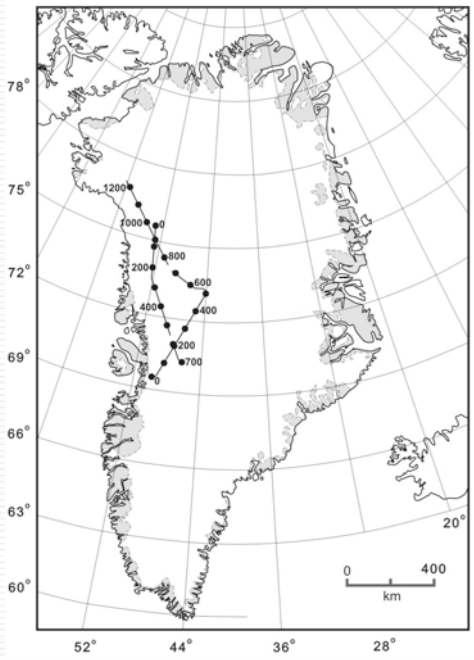
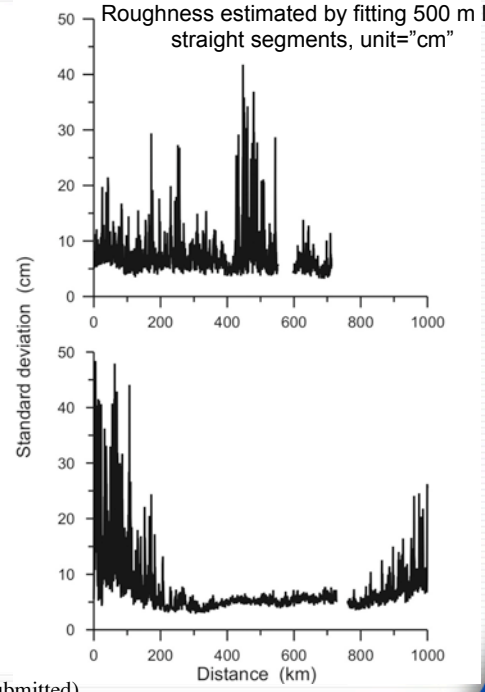


(from van der Veen et al., submitted)

- Roughness map of northern Greenland from ATM profiles
- Contour lines = black; transects = grey
- Roughness is estimated as the standard deviation of the residual obtained by fitting 500 m long segments
- Unit is “cm”

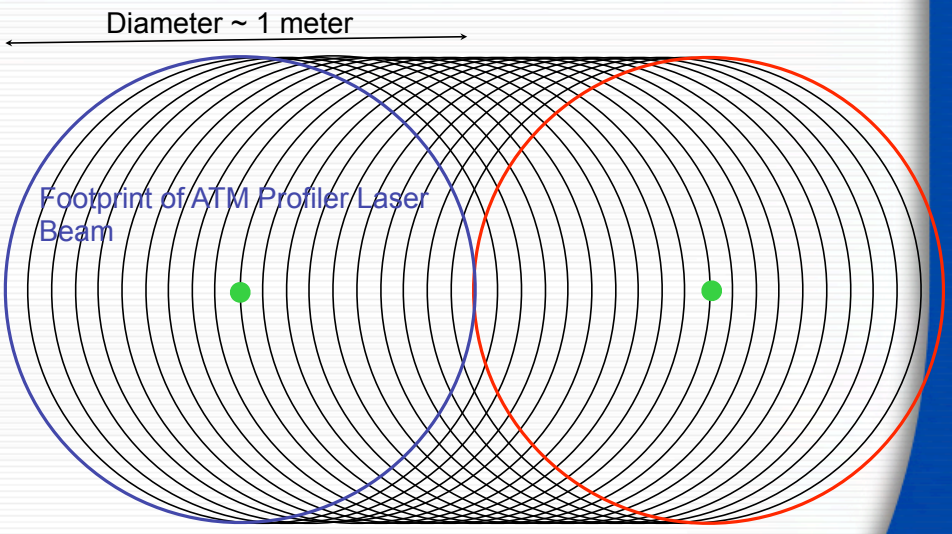


Roughness estimated by fitting 500 m long straight segments, unit="cm"



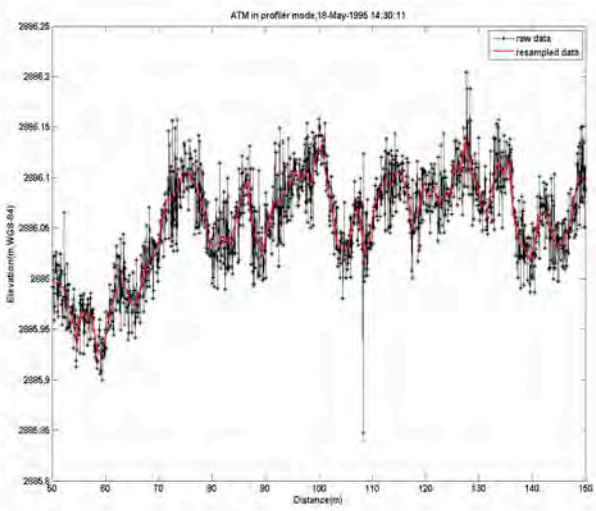
(from van der Veen et al., submitted)

Resampling ATM Profiler Data



nominal position of resampled points = 1 m spacing

Preprocessing of ATM elevations: Resampling/outlier detection



- Original data = black, resampled elevations = red
- Reduces redundancy
- Removes random noise
- Corrects the effect of rounding in lat/long position
- Creates small ascii files from large binary files with elevation as a function of distance
- All resampled data sets have 1 meter spacing and available for ICESat research
- Please send request to: gbabonis@buffalo.edu

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ICESat-II Performance Assessment

- Input: ATM profile, 1-m horizontal resolution
- Simulation of ICESat-II measurements by using ray-tracing
- Comparison of simulated ICESat measurements with “ground-truth” measurements to assess the effect of varying footprint size and spacing

Concept of the waveform simulator

- Simulates space-time waveforms:
  - Computes the number of photons collected by the receiver as a function of time.
  - Computes the travel time between the laser altimeter and the terrain and the energy distribution of the returned pulse.
- Handles various terrain data types:
  - Regularly spaced data, irregularly spaced data, profiler data

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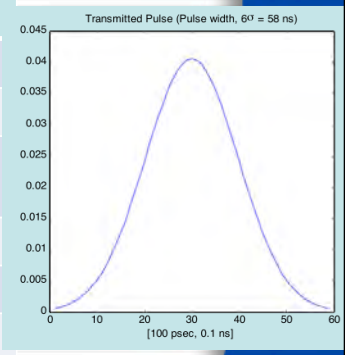
Algorithms

- Tessellate the footprint under the laser beam into cells.
  - Compute the amount of incident energy for each cell.
  - Determine contours equivalent to the travel time quantization.
  - Compute the area enclosed by the contours.
  - Convert the area into energy.
  - Convert the returned energy into the number of photons.
- Repeat the above process for all cells.

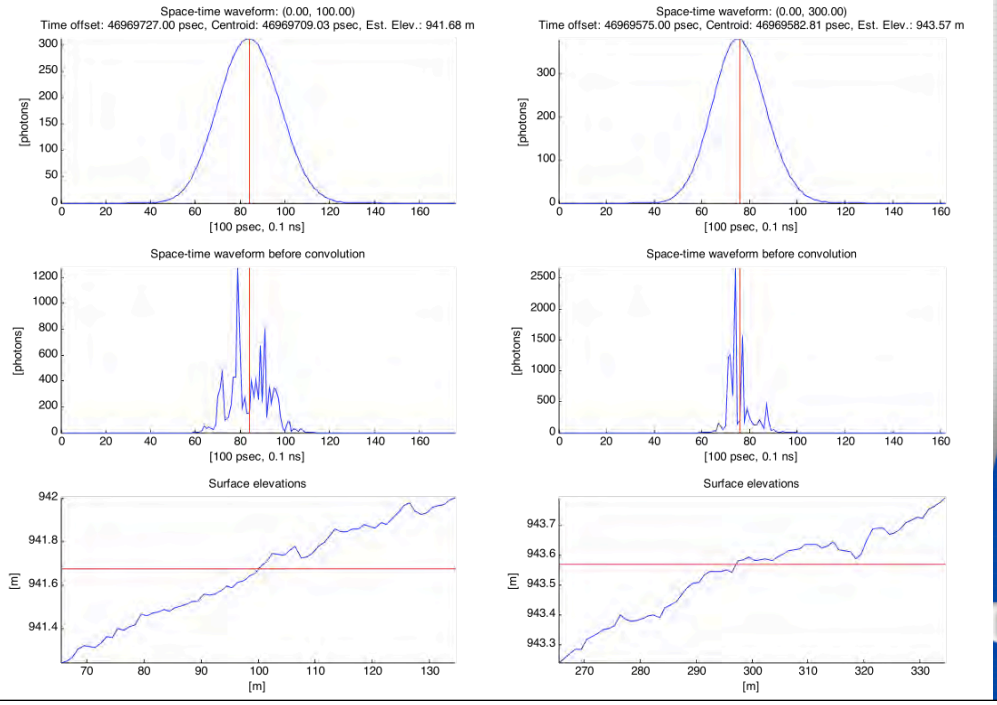
Parameters used in experiments

Parameter name	Value
Orbital altitude	705 km
Transmitted pulse width	5.8 ns (equivalent to 6σ)
Speed of light	2.9972925 X 10^{-2} m/100psec
Laser wavelength	1.064 μm
Plank constant	6.625 X 10^{-34} J/sec
Transmitted energy	0.1 J/shot
Telescopic receiver area	0.5 m^2
System transmission	0.5
Atmospheric transmission	0.5
Footprint size (diameter)	20 ~ 100 m (equivalent to 6σ)

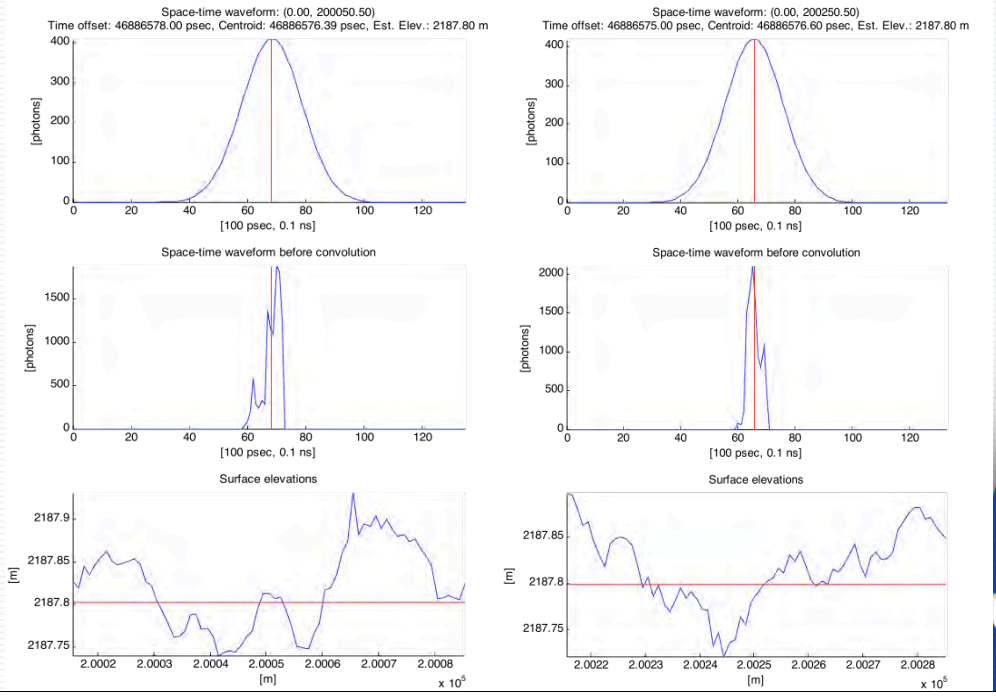


Transmitted Pulse

Examples of simulated waveforms (0~50km)



Examples of simulated waveforms (200~250km)



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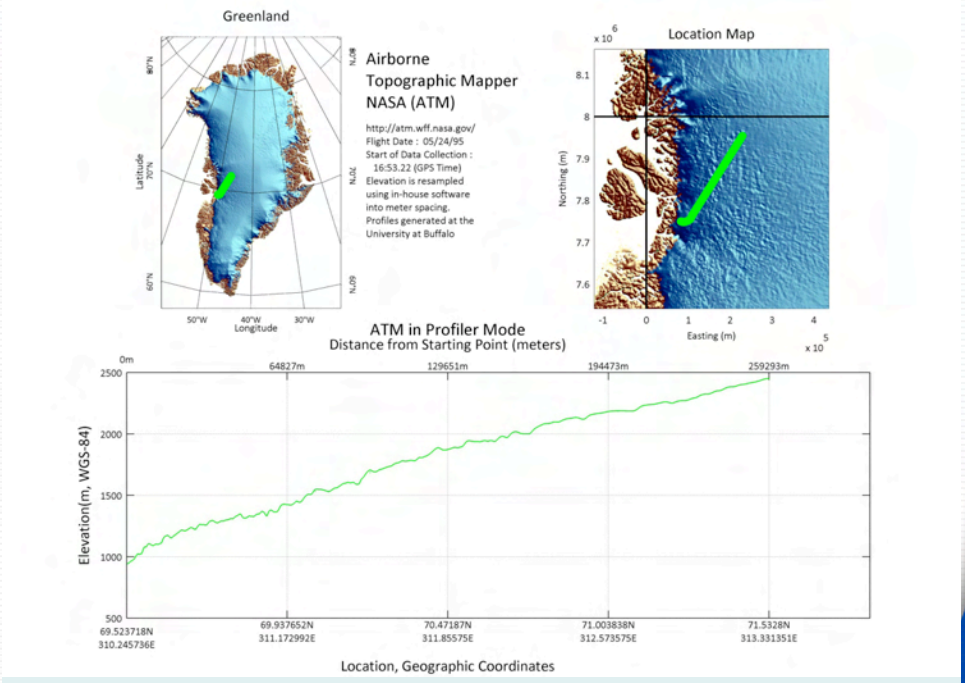
Experiment Design
Surface Reconstruction

- Elevations are interpolated from simulated ICESat observations and compared with elevations of deterministic ice surface estimated from ATM profiler measurements. Zero RMS difference would mean perfect surface reconstruction. Smooth surface is obtained from ATM observations by fitting a quadratic function within a 400 meter moving window to remove stochastic signal/ surface roughness.
- Elevations are compared:
  - at locations of ICESat measurements
  - between ICESat observations (max interpolation error):
    - Linear interpolation of two neighboring ICESat elevations
    - Quadratic fitting to four neighboring ICESat observations

Change Detection Experiment

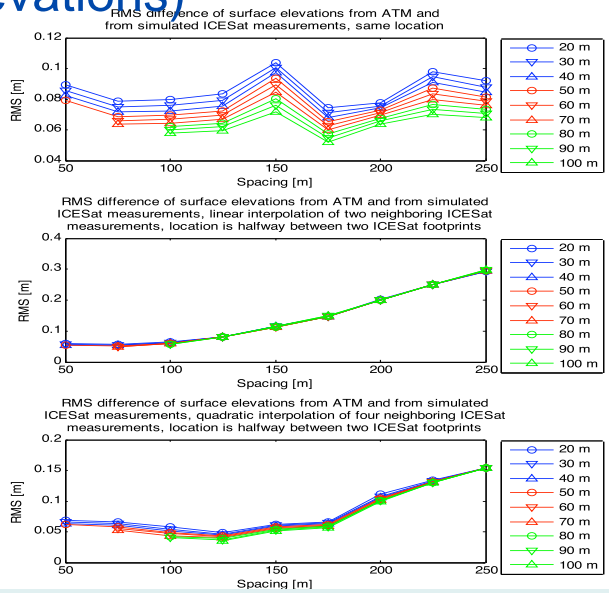
- Repeat ICESat surface elevation measurements are being simulated along the same ATM profiles, but at different locations. Elevation change equals to zero and difference characterizes the error in change detection.

Jakobshavn drainage basin low/high elevations



Jakobshavn drainage basin (05/24/95 16:53:22, 0 ~ 50 km and 200 ~ 250 km)

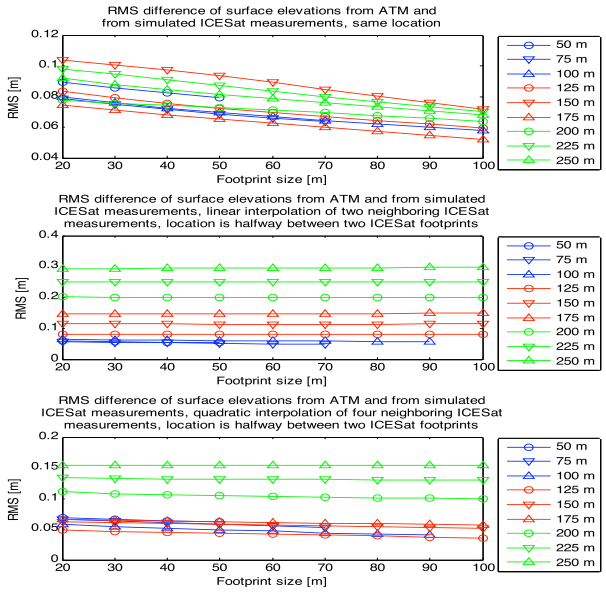
Surface reconstruction (low elevations)



Surface elevation is estimated by quadratic fit to ATM profile (400 m segment).

Jakoshavn drainage basin, low elev. (05/24/95 16:53:22, 0 ~ 50km)

Surface reconstruction (low elevations)



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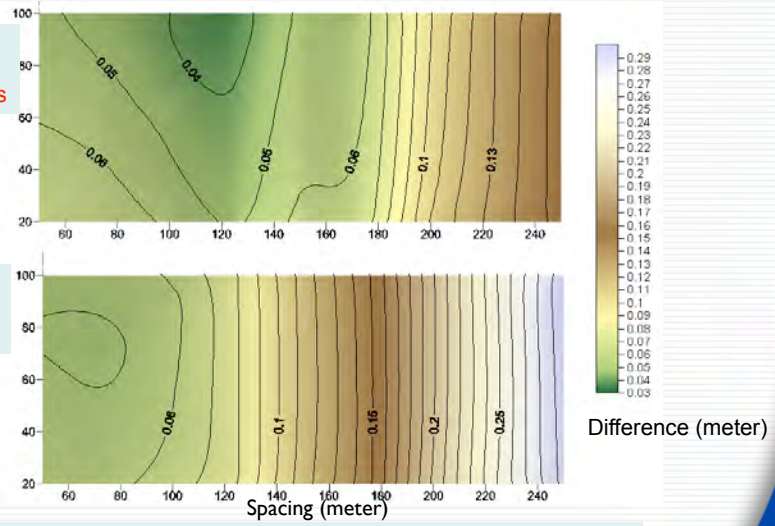
Jakobshavn drainage basin, low elev. (05/24/95 16:53:22, 0 ~ 50km)

Surface Reconstruction

RMS difference of interpolated ICESat elevations and ice sheet surface elevation estimated from ATM observations by fitting a quadratic function to 400 meter long sections

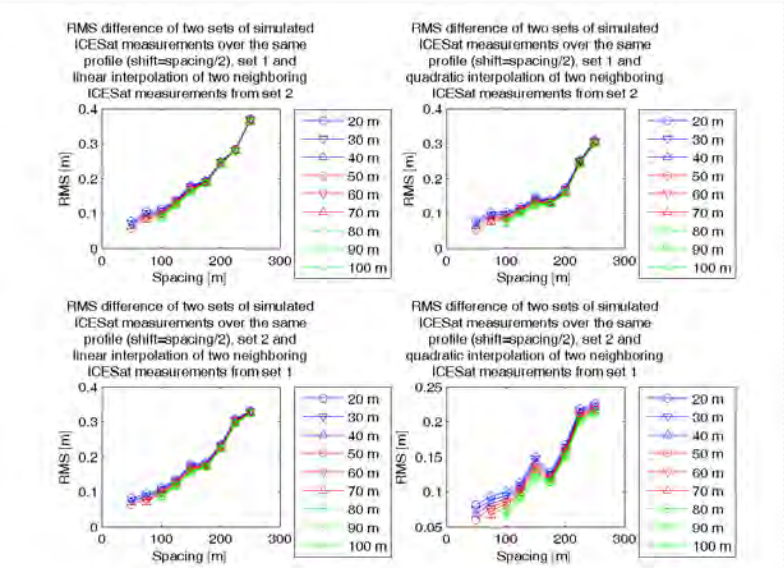
Quadratic interpolation of ICESat observations

Linear interpolation of ICESat observations



Jakobshavn drainage basin, low elev. (05/24/95 16:53:22, 0 ~ 50km)

Change detection (low elevations)



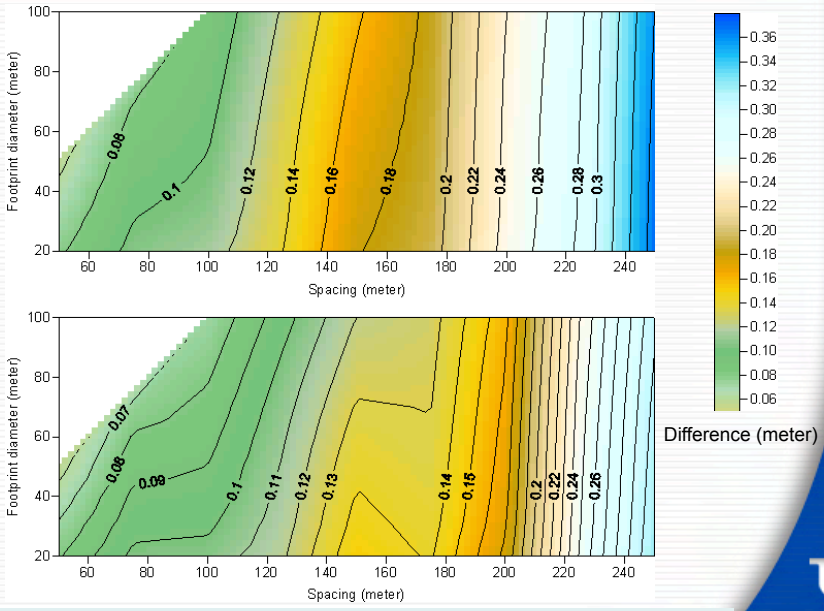
Jakobshavn drainage basin low elevations (05/24/95 16:53:22, 0 ~ 50km)

Change Detection

RMS difference of two sets of simulated ICESat measurements over the same profile (shift=spacing/2), set 1 and interpolated data from set 2

Linear interpolation of Set 2 ICESat observations

Quadratic Interpolation of Set 2 ICESat observations



Jakobshavn drainage basin low elevations (05/24/95 16:53:22, 0 ~ 50km)

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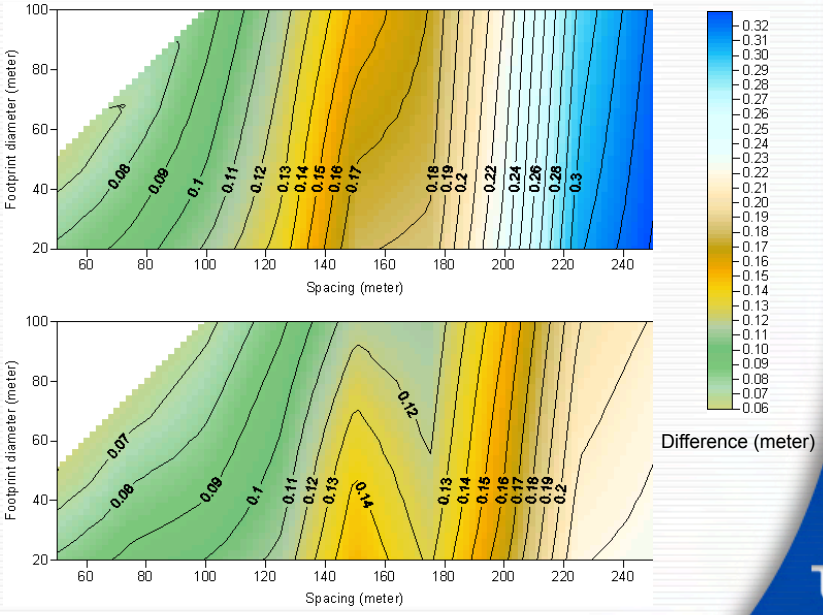
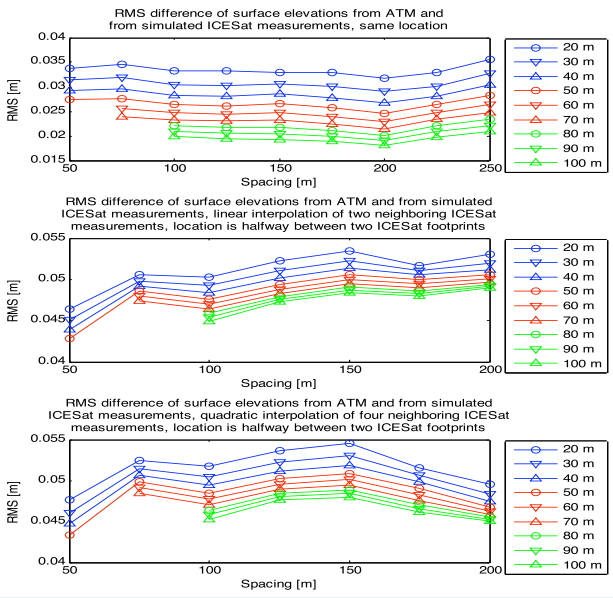


Csatho, Schenk

Jakobshavn drainage basin low elevations (05/24/95 16:53:22, 0 ~ 50km)

Surface reconstruction (high elevations)

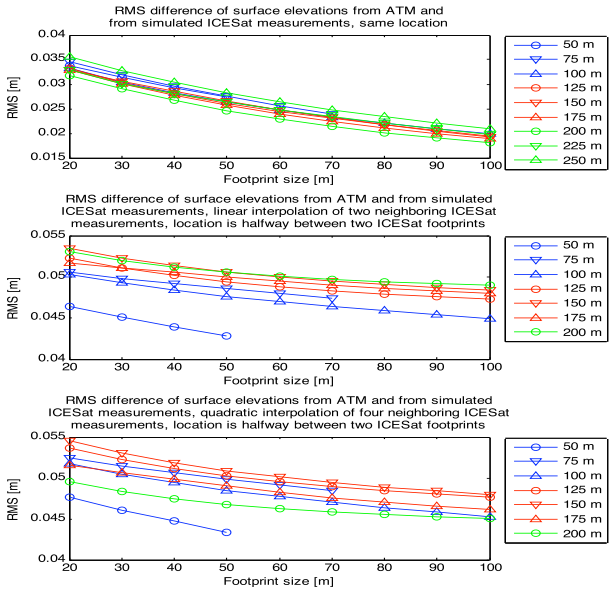


Surface elevation is estimated by quadratic fit to ATM profile (400 m segment).

Csatho, Schen

Jakoshavn drainage basin, high elev.(05/24/95 16:53:22, 200~250km)

Surface reconstruction (high elevations)



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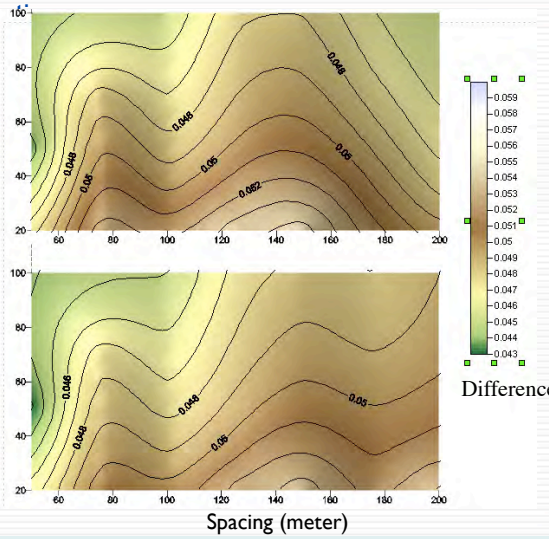
Quadratic interpolation of ICESat observations

Footprint diameter (meter)

Linear interpolation of ICESat observations

Footprint diameter (meter)



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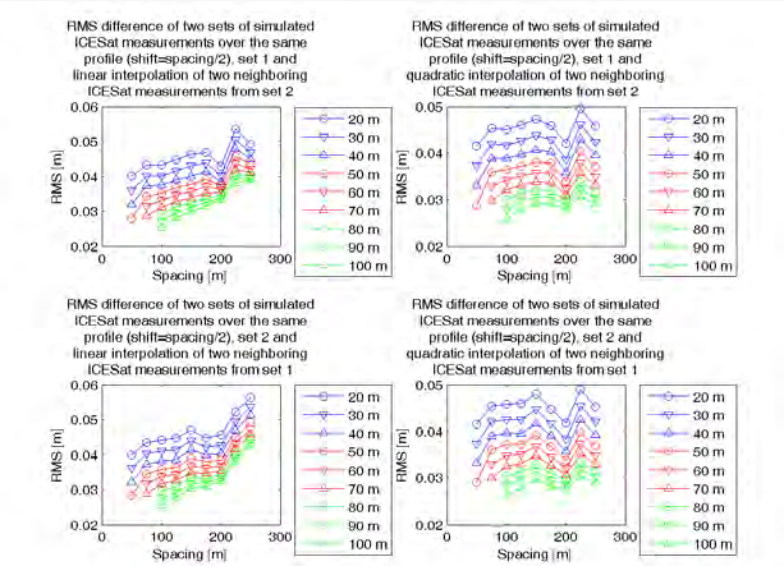

Jakobshavn drainage basin high elevations (05/24/95 16:53:22, 200~250km)

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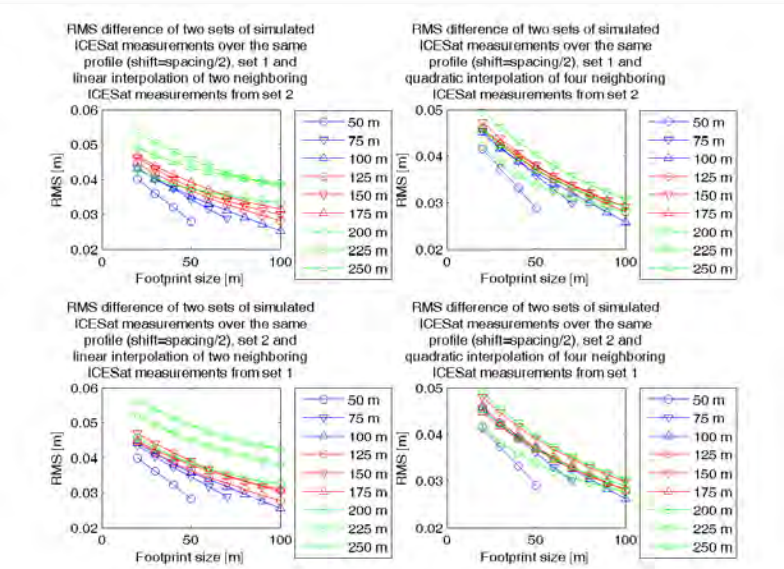

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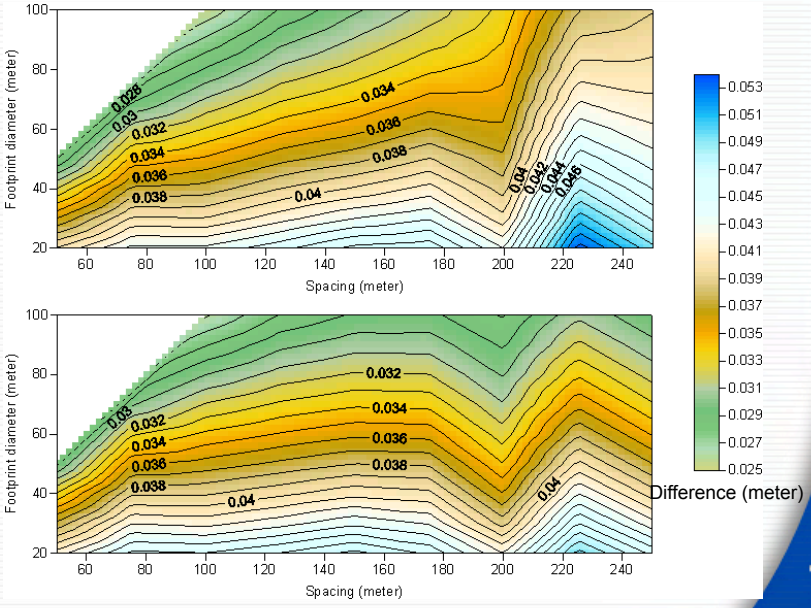

Csatho, Schenk et al., Jakobshavn drainage basin high elevations (05/24/95 16:53:22, 200~250km)

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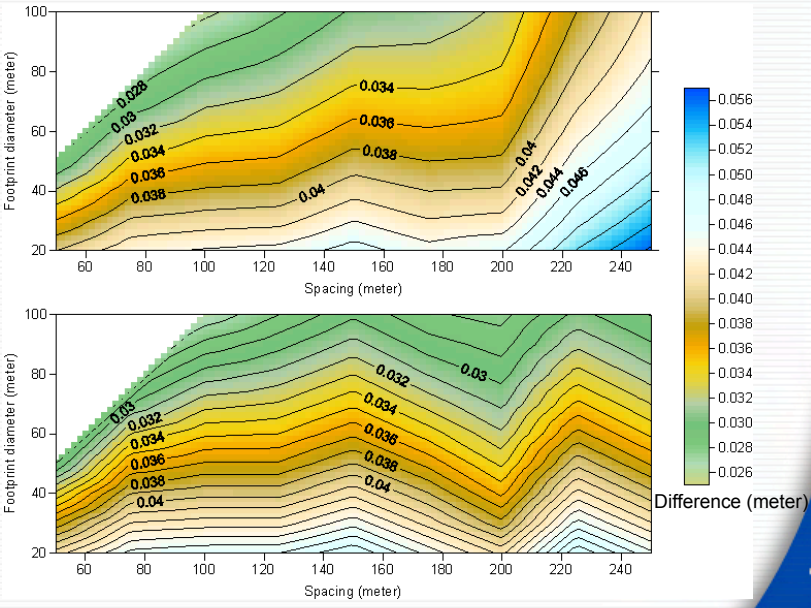
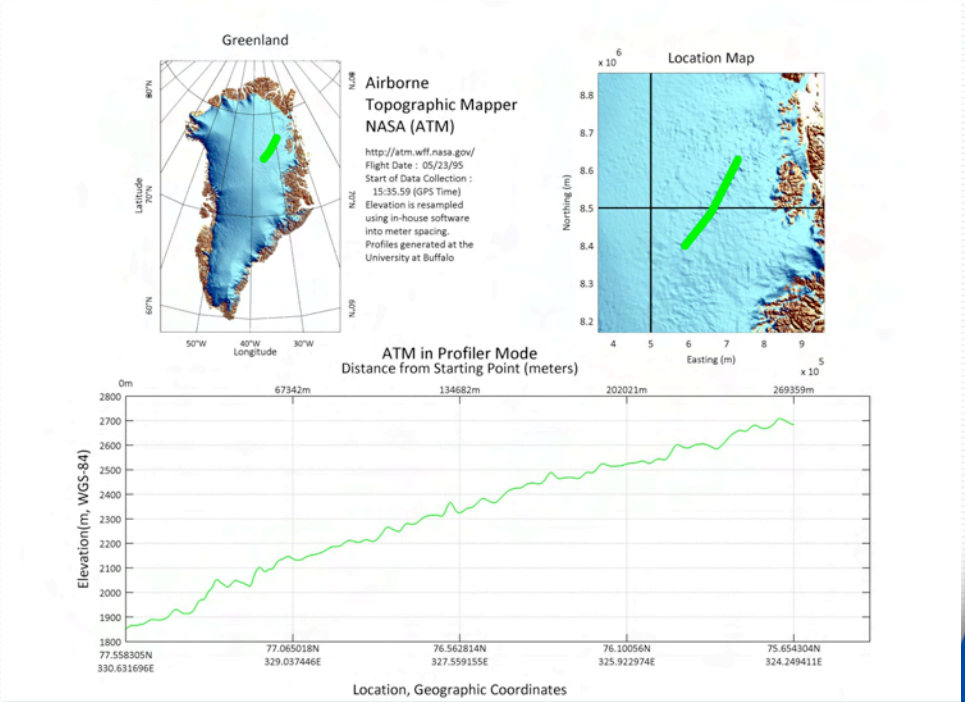


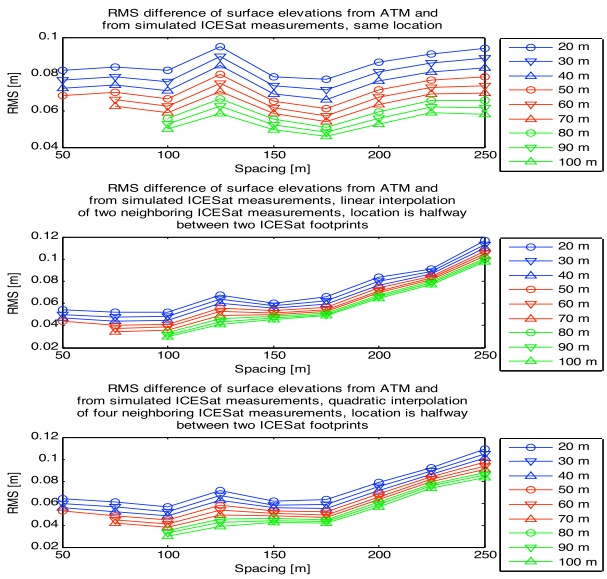
Csatho, Schenk et al., Jakobshavn drainage basin high elevations (05/24/95 16:53:22, 200~250km)

Greenland NE Ice Stream, center line



Greenland NE Ice Stream (05/23/95 13:35:59, 0 ~ 50 km)

Surface reconstruction



Surface elevation is estimated by quadratic fit to ATM profile (400 m segment).

NE Ice Stream, center line (05/23/95 13:35:59, 0 ~ 50km)

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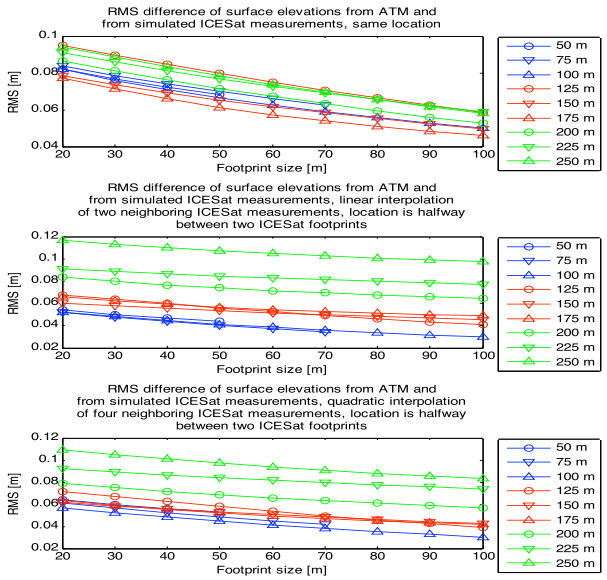
Surface reconstruction



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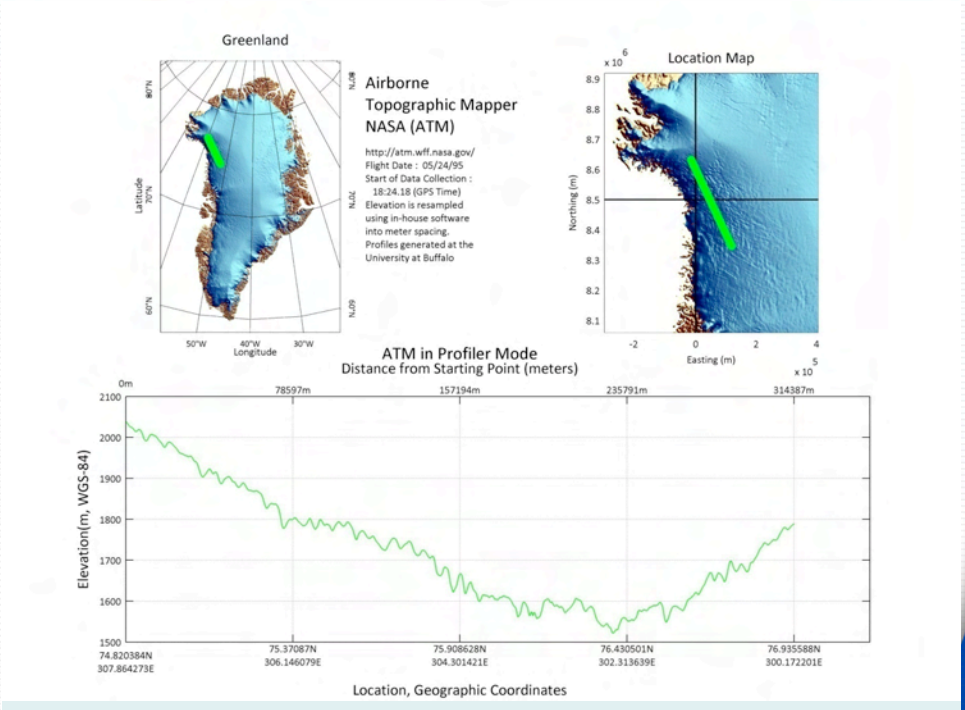
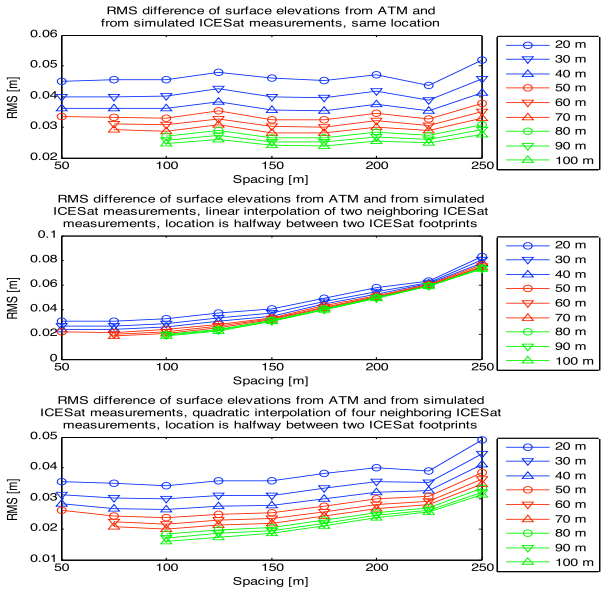
NE Ice Stream, center line (05/23/95 13:35:59, 0 ~ 50km)

Greenland NW coast



Greenland NW coast (05/24/95 18:24:18, 0 ~ 50 km)

Surface reconstruction



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NW coast (05/24/95 18:24:18, 0 ~ 50km)

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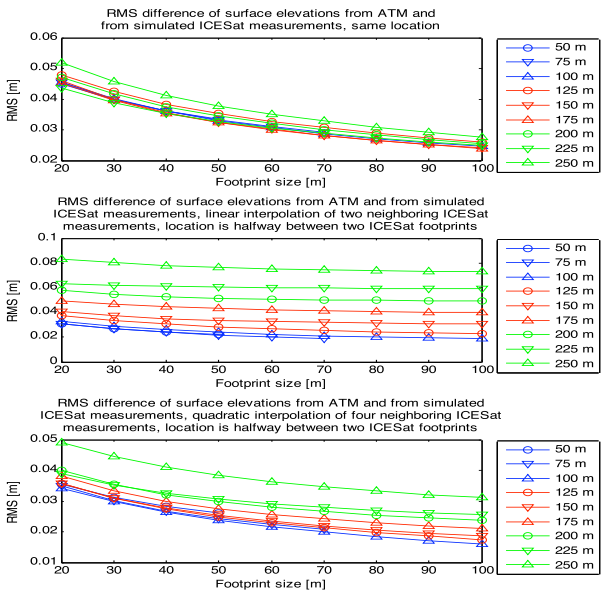
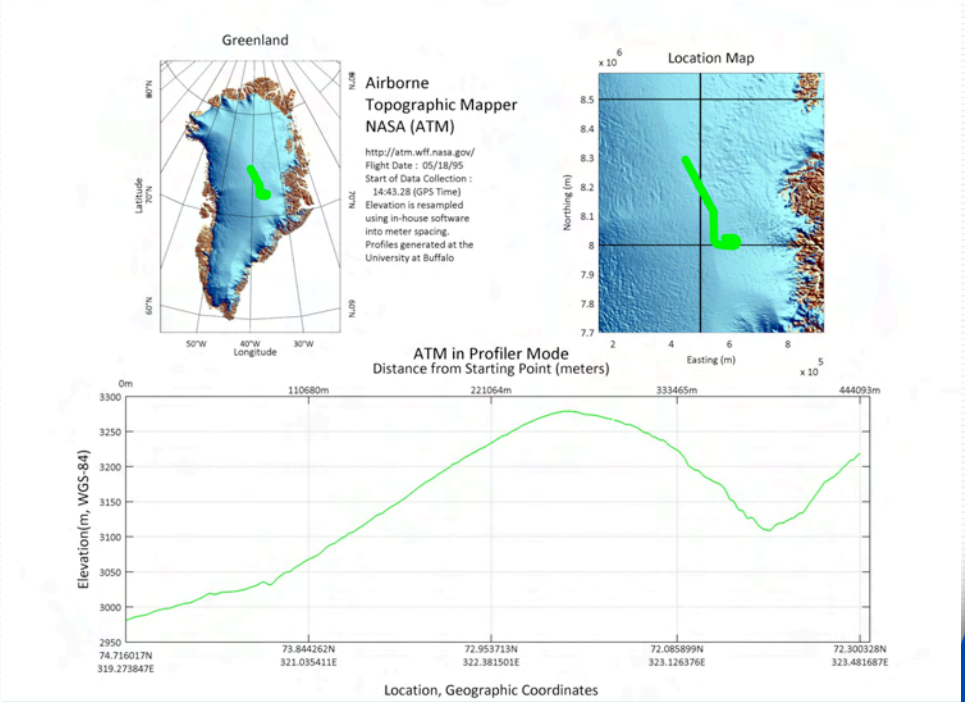
Surface reconstruction



Surface elevation is estimated by quadratic fit to ATM profile (400 m segment).

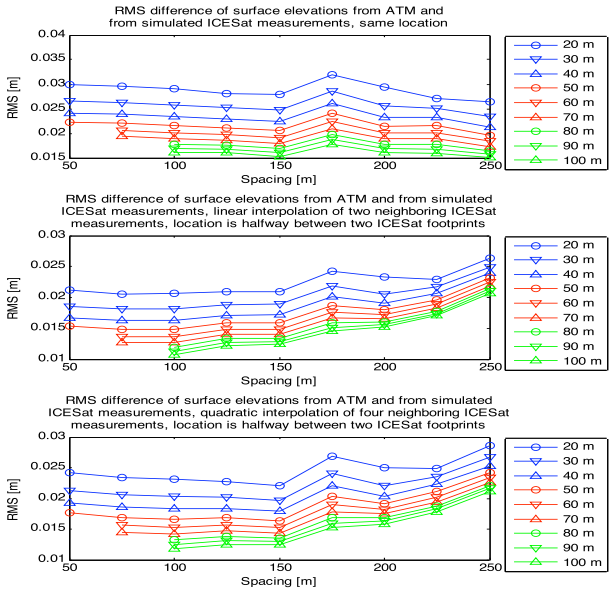
NW coast (05/24/95 18:24:18, 0 ~ 50km)

Greenland Ice Divide 1



Greenland Ice Divide 1 (05/18/95 14:43:28, 221 ~ 271km)

Surface reconstruction



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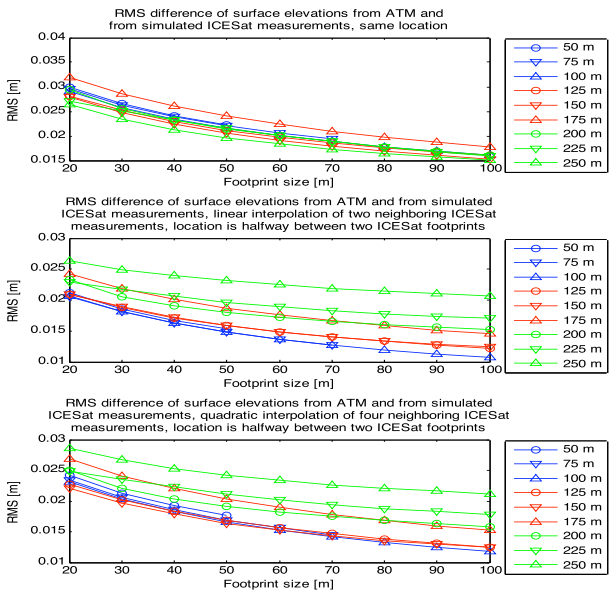
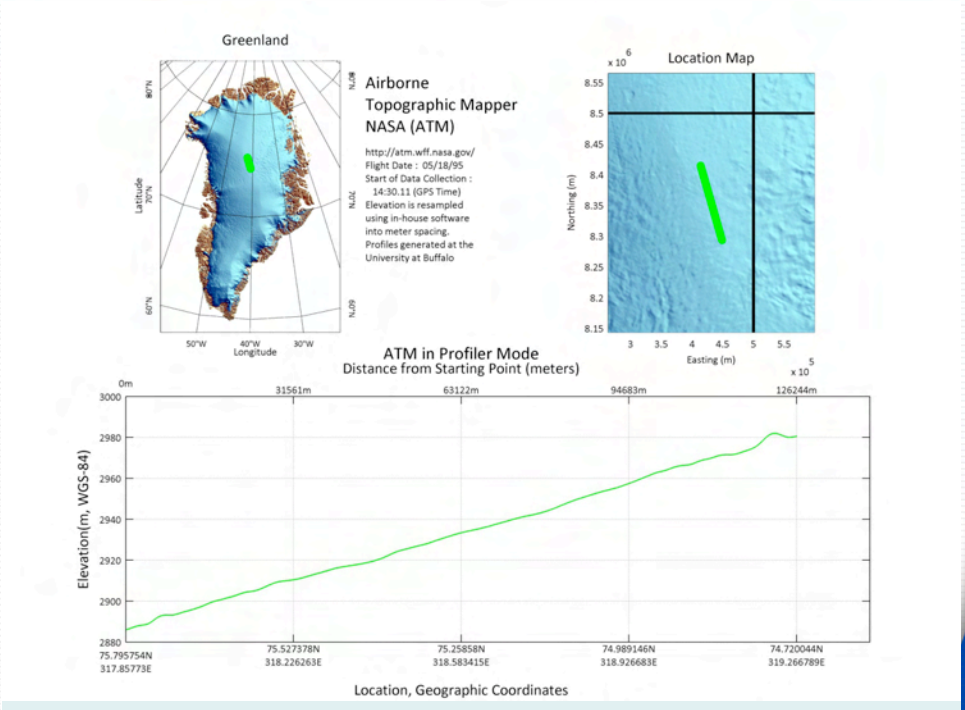
Surface reconstruction



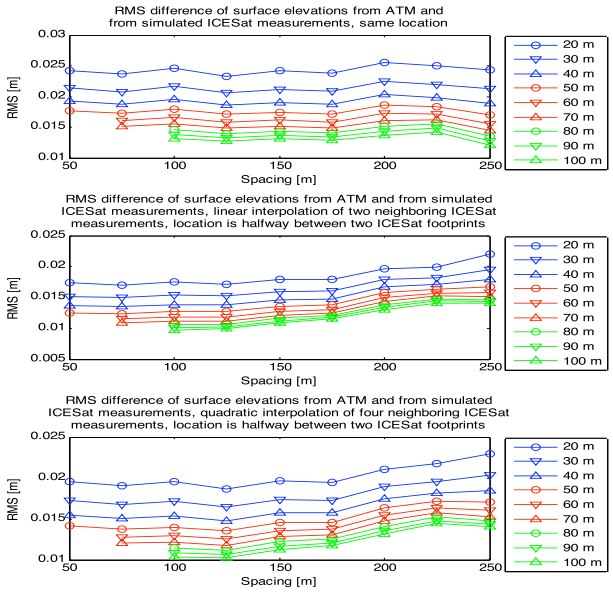
Surface elevation is estimated by quadratic fit to ATM profile (400 m segment).

Greenland Ice Divide 2



Greenland Ice Divide 2 (05/18/95 14:30:11, 0 ~ 50 km)

Surface reconstruction



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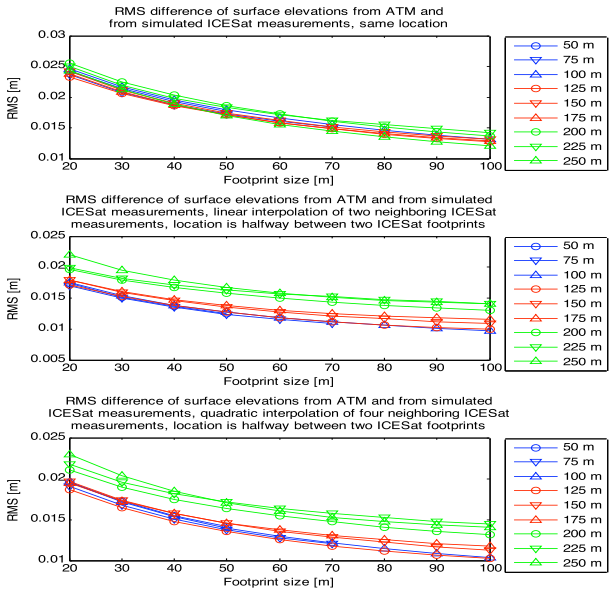
Surface reconstruction



Surface elevation is estimated by quadratic fit to ATM profile (400 m segment).